Factory Acceptance Test
for the
Transflow 2000 Battery At Premium Power
July 18-21 2011
for delivery to
Kotzebue Electric Association.

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Background

Wind Diesel hybrid systems have been installed and used in several Alaska communities over the past several years, with some success. However, in several communities, diesel fuel savings have been lower than expected due to the need to have the inability of the wind power to follow the community load, forcing the diesel engine to compensate for the varying difference between wind power and load. This sometimes results in the diesel engine operating at non-optimal conditions, thus reducing the expected savings from installing the wind turbine.

Adding a battery to the system to smooth out the variability of wind gusts (load leveling) as well as storing energy for later use (energy storage) has been proposed, but cost is a major issue. For example, the NGK Sodium Sulfur Battery has been considered, but it has a high cost and short lifetime indicate that little savings could be realized by installing such a battery.

The Premium Power Transflow 2000 is a 500 kW, 2.8 MW-hour battery based on a Zinc-Bromide technology. Low cost materials are used in the construction of the battery, and long term operation has been demonstrated (over 25 years for laboratory systems), indicating that this battery might prove to be cost effective for use in Wind-Diesel hybrid systems. In 2009, the NRECA negotiated a contract to purchase 8 of these batteries for demonstration, but funding for this large purchase was not obtained. Kotzebue Electric Cooperative elected to exercise a flow-through clause of the contract (the only utility to do so), at a price of about $1,050,000.

The contract negotiated allowed a buyer's representative to inspect the battery before shipment, and a Factory Acceptance Test (FAT) was also required, though the exact details of either the inspection or the FAT were not included in the purchase documents. At a meeting on April 28, 2011 at Premium Power, a test matrix was proposed:

Factory Acceptance Tests Specified		
Energy, Power and Efficiency	**Parameters**	**Results**
1. Full Charge/Full and Fractional Discharge Tests	· Perform at 100% full rated input/output · Set Discharge rate to 100% · Record full-cycle run time (both charge and discharge states) under full load · Repeat at 60% and 30% rated output	· Verify Charge rate of 315kW per hour over 10 hours · Verify Discharge Rate of 500kW per hour for 5 to 6 hours
2. AC Round Trip Efficiency	· Perform at 100% full rated input/output · Record input rms voltage and current · Record output rms voltage and current · Record temperatures · Repeat at 60% and 30% rated output	· Verify AC Round Trip Efficiency at 100% full rated input/output is between 63% and 70%
Functional Use Case Tests	**Parameters**	**Results**
1. Response to Remote Commands via DNP3	· Perform at scheduled input/output · Effect a charge, discharge or standy condition through DNP3 command or schedule · Time duration of 5 minutes per request	· Verify TF2000 can respond to commanded operation or scheduled commands
2. Reliability	· Preprogram a three day schedule into the TF2000 to operate various quadrants at various charge and discharge conditions for a variety of preprogrammed durations	· Verify TF2000 can operate autonomously for a period of three days

The above matrix represents goals stated by Premium Power for the purpose of the Factory Acceptance Test.

In addition to the matrix above, the technical specifications given as Attachment 1 to the purchase order must be met, including the requirement that the battery be capable of storing 2.8 MW-hr of energy.

Results:

General Discussion:

The Buyer's representative arrived at Premium Power on Tuesday, July 19, 2011. At the time of arrival, the Transflow 2000 unit was on the test bed, and being charged. The unit was accessed using a web based interface, and charging was observed from the company manufacturing facility, located several miles from the testing facility. The unit was observed operating in discharge later in the day.

During discussions with the Premium Power engineers, it was noted that this unit is the first Transflow 2000 to be sold and shipped to a customer. The unit on the test bed had been operated for 12 weeks, completing a variety of tests for EPRI, which was "renting" the unit to complete a variety of tests.

During the afternoon of July 19, the battery was observed on the test bed at Billerica. The battery being tested was a complete Tranflow 2000, with all eight stacks in place. The unit was operating with two

operators watching the unit. Power to the unit was provided with a 1MW Caterpillar Diesel engine, and load was applied through multiple load banks.

Energy, Power and Efficiency, task 1, Full Charge and Fractional Discharge Tests.

Results from the multiple tests of the battery conducted between May and July 2011 were given to the buyer's representative in a Powerpoint file on Friday, July 22.

Multiple tests were conducted over a period of about 12 weeks to measure the full cycle efficiency of the battery. The results of these tests were provided to the buyer's representative, and are given below:

TEST Results

Table 1: Charge/Discharge Tests Measurements Table

Cycle	Mode	Rate %	Average Loading / Charging Load (kW) (record actual measurements)	Date	Start Time	End Time	Total Time	Energy Efficiency	Coulombic Efficiency
1	Charge	100	313	7/1/2011	4:43 AM	10:49 AM	6:06		
	Discharge	45	224	7/1/2011	10:49 AM	4:30 PM	5:41	65	85.9
2	Charge	100	313	6/16/2011	8:01 AM	2:50 PM	6:49		
	Discharge	53	267	6/16/2011	2:50 PM	10:30 PM	7:40	67.4	86.2
3	Charge	100	313	6/22/2011	7:53 AM	2:08 PM	6:15		
	Discharge	53	267	6/22/2011	2:08 PM	7:06 PM	4:58	65.9	85.5
4	Charge	100	313	7/8/2011	8:26 AM	2:49 PM	6:23		
	Discharge	67	336	7/8/2011	2:49 PM	7:07 PM	4:18	62	85.7
5	Charge	100	313	5/5/2011	7:15 AM	1:21 PM	6:06		
	Discharge	100	500	5/5/2011	1:21 PM	4:57 PM	3:36	57.5	83.5
6	Charge	100	313	6/29/2011	8:05 AM	2:19 PM	6:14		
	Discharge	100	500	6/29/2011	2:19 AM	5:20 PM	3:01	58.5	89.3

At first look, it appears that the battery met the efficiency requirement of between 63% and 70% on runs number 1, 2, and 3. However, there are many ways to measure efficiency, and discussion with the PP representatives indicated these numbers are on the DC side of the battery, and as such does not include the pump parasitics (they are on the AC side of the bus) and the inverter efficiencies (reported to be in the high 90s).

Simply looking at the total kW-hrs in compared to the kW-hours out (multiplying average power times time) provides the following chart:

	kW-hr in	kW-hr out	DC efficiency
Run 1	1909.3	1273.067	67%
Run 2	2133.617	2047	96%
Run 3	1956.25	1593.1	81%
Run 4	1997.983	1444.8	72%
Run 5	1909.3	1800	94%
Run 6	1951.033	1508.333	77%

First, it is apparent that the battery does not have the advertised capacity of 2.8 MW-hours of capacity—the battery uses only approximately 2 MW-hours during charging, and provides only about 1.6 MW-hours in discharge.

It is also not clear why these simple numbers indicate a different efficiency than is given in the PP table.

Secondly, there is significant variability in the measured efficiency of the battery from cycle to cycle—why this is true is not clear from the information provided. It is not clear if each cycle was begun from a totally discharged state, or some other standard state, or if the battery discharge was stopped at a standard state.

In none of the cycles was a charge rate of 313 kW maintained for 10 hours—the average charge time was about 6 hours at 313 kW. Discharge times were also shorter than anticipated—runs 5 an 6 indicated discharge times of just over 3 hours.

AC estimates.

A simple spreadsheet model was created to estimate the AC efficiency for each run. This model included a fixed 30 kW pump parasitic for every load (it varies with load, but that information is not available at the time of this writing), and using a linear approximation of the electrochemical data provided by Premium Power. When these numbers are inserted, the efficiency drops to 52% on run 1, Run 2 is 76%, Run 3 is 54%, Run 4 is 59%, Run 5 is 79%, and run 6 is 65% efficient.

Communications:

This battery is the first Transflow 2000 shipped from Premium Power, and has been operated on the test stand since early May of 2011. The unit has been cycled multiple times, and is controllable through a computer interface. Therefore, the unit meets the communications test called for in the FAT.

No evidence has been presented to indicate the ability of the battery to operate unattended.

Summary

The results of the Factory Acceptance Test are somewhat mixed, and can be summarized as follows:

- The Transflow 2000 unit was assembled, complete, and operating at the FAT on July 18-22, 2001
- Communications with the battery through the internet were possible through a web page interface.
- Baseline data on performance was collected.
- The battery did not demonstrate the expected energy storage capacity of 2.8 MW-hrs, instead providing only about 1.6 MW-hours of DC power.
- In multiple tests, the efficiency of the battery varied considerably, for unknown reasons.

If this were a commercial utility purchase of a standard product, the responsible action would be to decline acceptance of the unit based on a failure to perform to expected levels. However, this project at Kotzebue Electric Association is funded largely through funds intended to demonstrate pre-commercial technologies and evaluate their possible use in Alaskan communities. The objective of the project is to test the hardware and assess its level of performance.